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ANALYSIS OF TUBE FAILURE IN ECONOMIZER AND SUPER HEATER TUBE IN THERMAL POWER STATION

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ABSTRACT

Boiler tube failure continues to be the leading cause for forced outages in fossil fired boiler. The tube failure may be a simple problem, unless it causes damage to the power plant and affects safety of the human being. The problem due to tube failure is realized only when the cost due to failure estimated. The main objective of our project is to reduce the number of tube failures occurring in boiler accessories at thermal power station by analyzing the reason behind the tube failure and provide suitable remedies for it. Tube failures in boiler accessories occur due to various reasons and major reasons for failure among the various reasons are flue gas erosion, long term overheating and steam erosion. The major failure reasons are taken from the tube failure. Major causes for failure can be controlled by using following remedies such as optimization of flue gas velocity, using tube material with better creep strength and by providing coating along the wall of the tube.

The optimization of flue gas velocity is done by computational fluid dynamics software (ANSYS fluent), the boiler tube material is chosen based on the cost, creep strength and corrosion resistance, the coating for boiler tube is chosen based on operating conditions and coating feasibility. Apart from the above, providing protection shield over tubes and griddling bands. The above remedies if implemented in the power plants can reduce the tube failure to a major extent. This paper deals with the Economizer tube and Super heater tube failure analysis in the Thermal Power Station, remedial measures to prevent tube failures and the benefits after implementing such remedial action.

KEYWORDS: Boiler Tube, Fluid Dynamics Software & Thermal Power Station

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Original Article

1. INTRODUCTION

Boiler tubes are set of long and several folds inside the furnace, sometimes their total length may be several kilometers mainly in the case of Thermal Power Plant boilers, and these tubes transfer heat from flue gas to water or steam. Figure 1.1 shows tubes of a typical water tube boiler in a power plant.

The following Table 1 shows the specification of economizer tubes in water tube boiler of Thermal power station.

Table 1

Tube material	SA210GrA1(C=0.27%) Tube
Tube dia	44.5mm
Tube thickness	4.5mm
Tube length	32 km(approx)
No of bends	14
Tube arrangement	Horizontal
Tube bend dia	65 mm

Figure 1.1: Tubes of a Water Tube

2. ECONOMIZER AND SUPERHEATER TUBE FAILURE ANALYSIS

This Explains about problems in boiler tubes and the factors that cause major damage to the boiler tubes. This helped to identify the major reasons for tube failures and suggest suitable remedies for the failures caused due to the problems.

2.1 Types of Failure

The following are different types of boiler tube failure:

- Fish mouth opening
- Window opening
- Burst open puncture
- Pin hole puncture
- Crack formation

2.2 Areas of Failure

Most of the failures in the boiler happen at repeated places. Places at which tube failures seen most are Economizer, Extended steam cooled coils, Water walls, Low temperature super heater, Reheater tubes, Platen super heater and Final super heater. All these places require very good maintenance for longer life and to reduce the failure rate occurring on it.

2.3 Causes of Tube Failure

There are numerous causes that accounts to the failure of boiler tube in water tube boilers. There are

- Erosion and Stress rupture
- Corrosion and Loss of quality

2.3.1 Erosion

There are various reasons behind the erosion of boiler like fly ash, coal particles etc. The factors that which causes erosion in boiler tubes are listed below.

- Fly ash and Coal particles
- Falling slag and Air erosion

2.3.1.1 Fly Ash

Fly ash travels with the flue gas at the same speed around 11m/s, when it continuously travels at this speed, it would erode the metal in constant manner, and finally it would reach the critical limit at which the tube could no more withstand the pressure.

2.3.1.2 Coal Particles

The following are the areas in boiler where coal particle erosion is usually experienced; Economizer bends and water wall tubes, Screen tubes, Goose neck portion at furnace top, Soot blower opening in the water walls, Wind box opening in the furnace, Bottom hoper tubes. Figure 2.1.1 represents the boiler tube erosion due to coal particle.

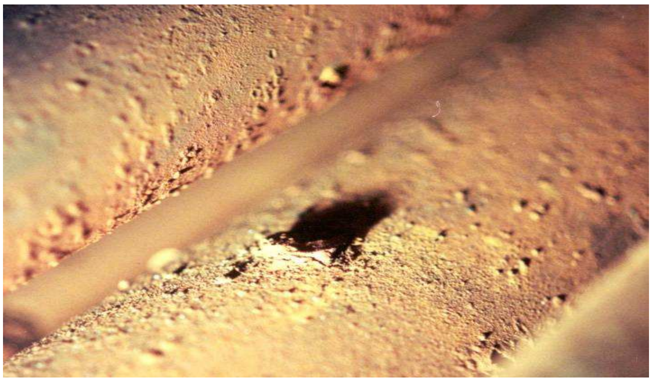

Figure 2.1.1: Coal Particle Erosion

2.3.1.3 Slag Formation

Slag is formed by the reaction of deposited ash particles with the boiler tube material, prolonged traveling of ash particles around boiler tube cause deposition of ash and at high temperature deposit, boiler tube particle reacts to form molten metal slag, this falls on the lower tube and erodes those tubes. Figure 2.1.2 represents the formation of slag around boiler tubes.

Figure 2.1.2: Slag Formed Around Boiler

2.3.1.4 Air Erosion

Continuous flow of hot air in the flue gas also causes considerable erosion, but when compared to other factors which is causing the erosion, it is bit lower.

2.3.2 Stress Rupture

Stress rupture is another important cause to the failure of boiler tubes, particularly in water tube boilers. Some reasons for the stress rupture of boilers are given below.

- Long term over heating
- Short term over heating
- Dissimilar metal welding

2.3.2.1 Dissimilar Metal Welding

In the Thermal Power Station, dissimilar metal welds are used to join ferrisite low-alloy steels to austenitic stainless steels. Unfortunately, these welds can fail prematurely from accelerated creep. However, atransition joint where the composition changes from austenitic steel to ferrisite steel, could replace then one dissimilar weld with two similar welds. Figure 2.1.3 shows the failure of dissimilar metal welds in boiler tube of a water tube boiler.

Figure 2.1.3: Dissimilar Metal Weld Failure

2.3.3 Corrosion

In corrosion boiler tubes, materials are taken away by chemicals around it. Some of reasons behind corrosion are given below.

- Caustic corrosion
- Pitting corrosion
- High temperature corrosion
- Low temperature corrosion

3. RESULTS AND SUGGESTED SOLUTION

3.1 Loads Acting on the System

- Primary loads
- Secondary loads

3.1.1 Primary Loads

Piping codes separate primary loads into two types, based on the duration of their application.

- **Sustained Loads**

Loads which can be expected to present, virtually at all times of plant operation. Examples would be internal fluid pressure and dead weight of the piping systems, which include pipe weight, insulation weight, component weight and fluid weight.

- **Occasional Loads**

Loads which are present only during a small fraction of the piping system operating time. Examples would be high winds, fluid hammer, relief valve discharge, earth quake and pipe break.

3.1.2 Secondary Loads

Secondary loads or expansion loads are those due to displacements of piping. Examples would be thermal expansion, sesamic anchor movements, thermal anchor movements and building settlement.

3.1.3 Load Combinations

Pipe supports must be designed to with stand any combination of loading, which is postulated to occur simultaneously. Typically as follows:

- dead weight (pipe weight+fluid weight+component weight+insulation weight)
- hydro test load (1 (above) –fluid weight+water filled weight)
- thermal expansion
- static thrust (safety valve opening, pressure thrust due to unties expansion joints)
- imposed forces loads(wind)
- dynamic load (fluid transient- steam hammer) time history curve These loads may be added either algebraically to arrive at realistic values or absolutely for added conservatism, according to the design criteria requirements.

3.1.4 Caesar II

Caesar II is one of the best PC –based pipe stress analysis software program, developed market and sold by COADE Engineering software.

3.1.4.1 Sustained Condition Stress

CAESAR II Ver.5.00.6, (Build 061102) Date: MAR 10, 2010 Time: 14.0

Job: C:\PROGRAM FILES\COADE\CAESAR II 5.00\super heater

Licensed To: -- ID#2304

Stresses Report:

Case 2 (SUS) W+P1

Piping Code: B31.1 – 2004, August 16, 2004

Code Stress Checked Passed

Highest Stresses: (kpa)

Code Stress Ratio: 20.25 @Node 20

Code Stress: 20257.1 Allowable: 100045.5

Axial Stress: 20310.6 @Node 20

Bending Stress: 350.4 @Node 20

Torsion Stress: 0.0 @Node 10

Hoop Stress: 44861.2 @Node 20

3D Max Intensity: 62564.7 @Node 20

Table 2

NODE	Bending Stress kpa	Torsion Stress kpa	SIF In Plane	SIF Out Plane	Code Stress	Allowable Stress kpa	Ratio %
10	29	0.0	1.000	1.000	19936	100046	20
20	350	0.0	1.000	1.000	20257	100046	20
20	350	0.0	1.000	1.000	20257	100046	20
30	55	0.0	1.000	1.000	19962	100046	20
30	55	0.0	1.000	1.000	19962	100046	20
40	29	0.0	1.000	1.000	19936	100046	20

3.1.4.2 Expansion Condition Stress

Caesar II Ver.5.00.6, (Build 061102) Date: MAR 10, 2010 Time: 14.0

Job: C:\PROGRAM FILES\COADE\CAESAR II 5.00\super heater

Licensed To: -- ID#2304

Stresses Report:

CASE 3 (EXP) L3=L1-L2

Piping Code: B31.1 – 2004, August 16, 2004

Code Stress Check Passed

Highest Stresses: (kpa)

Code Stress Ratio: 0.38 @Node 40

Code Stress: 891.8 Allowable: 234395.9

Axial Stress: 2.4 @Node 10

Bending Stress: 891.8 @Node 30

Torsion Stress: 0.0 @Node 20

Hoop Stress: 0.0 @Node 20

3D Max Intensity: 891.8 @Node 10

Table 3

NODE	Bending Stress kpa	Torsion Stress kpa	SIF In Plane	SIF Out Plane	Code Stress	Allowable Stress kpa	Ratio %
10	892	0.0	1.000	1.000	892	234396	0
20	844	0.0	1.000	1.000	844	234075	0
20	844	0.0	1.000	1.000	844	234075	0
30	757	0.0	1.000	1.000	757	234372	0
30	757	0.0	1.000	1.000	757	234372	0
40	892	0.0	1.000	1.000	892	234396	0

3.2 Pipe Stress Analysis Results

From the algebraic stress calculations and CAESAR II pipe stress analysis, it is found that the actual sustain condition stress in the pipes is 20257.1 kPa. Allowable sustained condition stress limit is 100045.5 kPa. Similarly, the actual expansion condition stress in the pipe is 891.8 kPa. Allowable expansion condition stress is 234395.9 kPa (As per clause no. of article 391 A of version of IBR 1950) the stresses are within the allowable limit.

All the results of the analysis are within the allowable limits. The stresses acting in the pipe line and the forces and moments acting at the boiler end and the main steam common header end are compared with the code requirements, and they are within the allowable limits. Finally, we came to know that the boiler tube failures are caused due to flue gas stagnation in the super heater zone

3.3 Suggested Solution

The failure of the Economizer and super heater tubes at the front positions is mainly due to overheating of tubes caused by flue gas flow stagnation. This can be prevented by adopting the following measures,

- Providing wear protection shield over tubes.
- Providing gridling band over tubes.

3.4 Wear Protection Shield

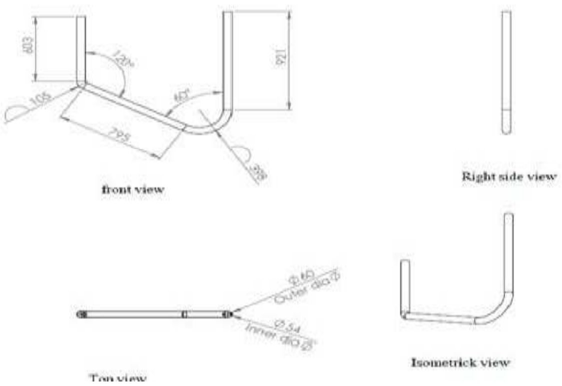

Figure 3.1: Drafting Model of the Shield

Figure 3.2: Shield Placement

3.5 Design of Girdling Band

Maintain design flow pathways at lower portion by provision of alignment or girdling bands. The girding bands must be provided at an interval of say 1.3 meter from the bottom and 1.3 meter from the top, so that the super heater tubes remain in position throughout the length. The bands provided shall be such, so as not be restrict free downward expansion of the coils. This will also ensure the velocity of the flue gas remains as per design.

Remove the freely laid top layer of refractory bricks on the ridge and smoothen the windward and leeward slopes of the ridge with cast able refractory to facilitate a smooth laminar flue gas flow around the ridge.

The girdling band is designed in two halves, which are bolted together on the super heater tubes. Stainless steel material is suggested for the girdling bands. Each half of the girdling band has 16 half round pipes to support the super heater tubes and these half round pipes are welded on the stainless steel flat then both the halves are bolted together to maintain the alignment of the super heater tubes. The design is initially made in two dimensions using the AutoCAD software, then the three dimensional model is created.

3.5.1 Fabrication

The girdling bands can be fabricated using the welding process. The stainless steel flat and the half round pipe have to be welded together, the spacing between each half round pipe are depicted in the auto cad drawing. For the clamping of the two halves of the girdling band together bolt and nut arrangement is used, seven holes are drilled in each flat for this purpose.

3.6 Economic Significance of the Project

Power generation is a capital intensive sector and a disruption in power generation due to equipment failure leads to huge monetary losses. Prevention of equipment failure and reducing the maintenance downtime are the challenges faced by the engineers.

A twenty four hour shut down of a 210 MW unit for failure rectification will lead to a generation loss of 5040 MWh and monetary loss of 126,00,000/-. A failure in the super heater tube or Economizer tube requires a minimum of 48 hours towards failure rectification, leading to a generation loss of 10080 MWh.

The probability of downtime due to super heater tube or Economizer tube failure in the boiler is 10%–15%, and by providing the girdling bands to the super heater tubes and also by providing protection shield over the Economizer tubes, it can be minimized to 5–8% i. e. a 50% reduction in downtime probability.

Our project work would help in the reduction of downtime probability of boiler super heater tube or Economizer tube failure by 50%, resulting in prevention of large generation and economical losses.

Figure 3.3: Girdling Band for Primary Super Heater Coil

Figure 3.4: Girdling Band for Secondary SH Coil Assembly

4. CONCLUSIONS

The following conclusion can be drawn from the study.

Tube failure study in Economizer and Super heater zone has been taken at NCTPS – Stage-I Boilers. From the failure data, we come to conclude that the three major reasons for the tube failure is flyash erosion, long term overheating and steam erosion. In above three, flyash erosion is the main cause for tube failure. Failure due to fly ash erosion is reduced if coating such as electro deposited inner metallic coating, weld overlay coating and thermal spray coating are applied on the Boiler tube surface. But coating can be done every year and needs more time.

The best method to reduce tube failure and down time of boiler, we go for providing protection shield and gridling bands over the surface of the tube. Providing protection shield and gridling bands are cheaper than applying coating over Boiler surface. Also, providing protection shield and providing gridling bands are taken less time than applying coating. In convection super heater zone, the failure of tubes at front position is mainly due to overheating of tubes caused by flue gas stagnation. This can be rectified by providing gridling bands at an interval of 1.3 meter from the bottom and 1.3 meter from top, so that the super heater tubes remain in position throughout the length.

The above remedies if implemented in power plants, not only reduced tube failure, but also reduce the repair cost of tubes, increase the availability of boiler and less interruption in power generation. The general suggestion to reduced tube failure is to use low as coal, which will reduce erosion rate and also reduce the major tube failure problems. The future presents several challenges, with expected tightening electricity market, likely to increase the cost of boiler tube failure, coming at a time when number of failures is expected to rise.

By providing protection shield over Economizer tubes and gridling bands over super heater zone, the down time of the Boiler canbe minimized from 10-15% to 5-8%.

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